77 Rec'd PCT/PTO 23 NOV 2001

FORM PTO-1390 (REV. 11-2000) US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEY'S DOCKET NUMBER **P/61800-PCT** U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/926592
INTERNATIONAL APPLICATION NO. **PCT/GB00/01979**	INTERNATIONAL FILING DATE **May 24, 2000**	PRIORITY DATE CLAIMED **May 24, 1999**

TITLE OF INVENTION **ELECTRO-OPTIC DEVICES**

APPLICANT(S) FOR DO/EO/US **Simon Howard SPENCER, William Philip PRITCHARD**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371 (f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [ ] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is attached hereto (required only if not communicated by the International Bureau).
   b. [X] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] An English language translation of the International Application as filed (35 U,S.C. 371(c)(2)).
   a. [ ] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   b. [ ] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [ ] A substitute specification.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [ ] Other items or information: **Receipt Acknowledgment Postcard**

JC19 Rec'd PCT/PTO 23 NOV 2001

U.S. APPLICATION NO.(if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/926592	PCT/GB00/01979	P/61800-PCT

21. [X] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1,040.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $890.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $740.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) $710.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$1,040.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	$0.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	24 - 20 =	4	x **$18.00**	$72.00	
Independent claims	2 - 3 =	0	x **$84.00**	$0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$280.00**	$0.00	
TOTAL OF ABOVE CALCULATIONS =				$1,112.00	
[ ] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$0.00	
SUBTOTAL =				$1,112.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$0.00	
TOTAL NATIONAL FEE =				$1,112.00	
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$0.00	
TOTAL FEES ENCLOSED =				$1,112.00	
				Amount to be refunded:	$
				charged:	$

a. [X] A check in the amount of <u>$1,112.00</u> to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________________ in the amount of $__________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>11-1145</u>. A duplicate copy of this sheet is enclosed.

d. [ ] Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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NAME

27,564
REGISTRATION NUMBER

09/926592

JC19 Rec'd PCT/PTO 23 NOV 2001

Docket No.: P/61800

PATENTS
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

I hereby certify that this correspondence is being deposited with the U.S. Patent Office by hand.

November 23, 2001 (date) Lisa Zumwalt

Lisa Zumwalt

International Application No.:		PCT/GB00/01979
International Filing Date	:	May 24, 2000
In re: Application of	:	Simon SPENCER, et al.
Deposited:	:	November 23, 2001
For	:	ELECTRO-OPTIC DEVICES

New York, New York
November 21, 2001

PRELIMINARY AMENDMENT

BOX: PCT
Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

Prior to calculation of the filing fee and before examination, kindly amend the above captioned application as follows:

IN THE CLAIMS:

Please cancel claims 1-26, without prejudice.

Please add the new set of claims set forth on the enclosed pages.

IN THE ABSTRACT:

Delete the "Abstract"on the PCT cover sheet and replace it with the "Abstract of the Disclosure" set forth on a separate sheet attached hereto.

REMARKS

An abstract has been provided on a separate sheet; and the claims have been amended to conform to U.S. practice.

Wherefore, an early action on the merits is earnestly solicited.

Respectfully submitted,

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ABSTRACT OF THE DISCLOSURE

An electro-optic device includes a polarizing beam splitter which sends a polarized component along a first path via birefringent cells and a differently polarized component via a second path through other birefringent cells. The two components are combined in a combiner, and the output is directed onto a CCD sensor. A modulator has a high transmission characteristic and allows faster switching. In one embodiment, the device is used to view differently polarized light from a scene.

PROPOSED NEW CLAIMS

27. An electro-optic device, comprising:

a polarizing beam splitter for producing first and second differently polarized components from applied unpolarized optical radiation;

first and second optical paths along which the first and second components respectively are directed; and

birefringent cell means in the first and second paths.

28. The device as claimed in claim 27, wherein the cell means comprises a first cell in the first path, and a second different cell in the second path.

29. The device as claimed in claim 27, wherein the cell means comprises a single cell which is included in both the first and second paths, the first and second components being applied to different regions of the single cell.

30. The device as claimed in claim 27, wherein the cell means is independently controllable in the first and second paths.

31. The device as claimed in claim 27, wherein the cell means includes a plurality of birefringent cells in the first path, and a plurality of birefringent cells in the second path.

32. The device as claimed in claim 27, wherein the first and second paths have optical outputs which are kept separate.

33. The device as claimed in claim 27, wherein the first and second paths have optical outputs which are combined.

34. The device as claimed in claim 27, and optical sensor means for receiving the components after they have traveled along the first and second paths.

35. The device as claimed in claim 34, wherein the optical sensor means includes charge coupled device means.

36. The device as claimed in claim 34, wherein the first and second optical paths have optical outputs which are kept separate and which are applied to respective different optical sensors, and wherein the sensors have outputs which are subsequently combined.

37. The device as claimed in claim 27, and analyzer means for receiving an output of the birefringent cell means.

38. The device as claimed in claim 27, wherein the beam splitter comprises a polarizing beam splitter cube.

39. The device as claimed in claim 27, wherein the birefringent cell means includes lead lanthanum zirconate titanate.

40. The device as claimed in claim 27, wherein the cell means have electrodes in the optical paths, and wherein the electrodes in one of the optical paths are offset with respect to the electrodes in the cell means in the other of the optical paths.

41. The device as claimed in claim 27, wherein the cell means is operable for producing at least three degrees of transmission through the device.

42. The device as claimed in claim 27, wherein the birefringent cell means is controlled to maintain an optical output of the device within a predetermined range during transmission through the device.

43. The device as claimed in claim 42, and a sensor for monitoring the optical output of the device, and means for deriving a control signal dependent on a monitored output, and for applying the control signal to the birefringent cell means.

44. The device as claimed in claim 42, wherein the birefringent cell means is controlled to prevent transmission during frame intervals of a sensor which receives the optical output.

45. The device as claimed in claim 27, wherein at least the beam splitter and birefringent cell means are parts of a single component.

46. The device as claimed in claim 45, wherein the first and second paths have optical outputs which are combined in an optical combiner operative for combining the first and second components after transmission through the cell means, and wherein the combiner forms part of the single component.

47. The device as claimed in claim 27, wherein the first and second polarized components are output in respective different colors.

48. The device as claimed in claim 27, wherein the birefringent cell means has optic axes in the optical paths, and wherein the optic axis in one of the optical paths is rotated relative to the optic axis in the other of the optical paths.

49. A camera apparatus including an electro-optic device comprising: a polarizing beam splitter for producing first and second differently polarized components from applied unpolarized optical radiation;

first and second optical paths along which the first and second components respectively are directed; and

birefringent cell means in the first and second paths.

50. The camera apparatus as claimed in claim 49, wherein the device is included within a focusing system of the camera apparatus.

ELECTRO-OPTIC DEVICES

This invention relates to electro-optic devices such as, for example, modulators or shutters which use birefringent material.

In these types of electro-optic devices, the application of an electrical field to the material causes its effective birefringence to change, resulting in rotation of its optic axis. This effect may be used to modulate incident optical radiation. Figure 1 illustrates a known simple electro-optic shutter configuration which comprises three elements, an input polariser P1, a birefringent cell C1 and an output analyser P2 (usually a second polariser). The birefringent cell C1 includes electrodes on its major surfaces to enable an electrical field to be produced in the cell C1 when a potential difference is applied across the electrodes. The shutter as illustrated in Figure 1 is subjected to unpolarised input radiation U which is incident on the input polariser P1. The light transmitted by input polariser P1 is linearly polarised and is incident on the cell C1. For zero field conditions, the state of the linearly polarised light is not altered as it passes through the electro-optic element and the light is absorbed by the second polariser P2 which is crossed relative to the input polariser P1. When a voltage is applied across the cell C1, it acts as an optical retarder, shifting the relative phases of light polarised parallel and perpendicular to the applied electric field. Thus linearly polarised light received at cell C1 is changed to elliptically polarised light at its output, a portion of which will pass through the second polariser P2. The transmissivity in the on-state may be maximized by adjusting the electric field such that the birefringent cell C1 behaves as a half-wave retardation plate, such that light is

linearly polarised at the output of the cell C1 with the plane of polarisation being rotated by 90°.

The performance of a shutter can be characterized by a number of performance parameters and the most suitable selected for a particular application. These parameters include the transmission (T_{ON}), extinction (T_{OFF}), response time (t_r), repetition rate (f_r), acceptance angle, power consumption and the spectral range over which the shutter is effective.

Figure 2 illustrates another optical shutter which has improved extinction, acceptance angle and power consumption compared to the shutter shown in Figure 1. In the Figure 2 device, two birefringent cells C1 and C2 are spatially arranged alternately along the optical path with three polarisers P1, P2 and P3. If the two cells C1 and C2 are each identical with the single cell C1 of the Figure 1 device, the same effect can be achieved at the output using approximately half the voltage applied across each of the cells. Thus, if say in the Figure 1 device, voltage pulses of 600V were applied across the cell C1 to switch it between states, in the device of Figure 2 each cell C1 and C2 is subjected to pulses of 300V, leading to a faster response time and increased repetition rate. Other improvements may be achieved by including coatings on the surfaces of the optical elements and by appropriate selection of the chemical composition of the birefringent material.

According to the invention there is provided an electro-optic device comprising: a polarising beam splitter which produces first and second differently polarised

components from applied unpolarised optical radiation; first and second optical paths along which the first and second components respectively are directed; and birefringent cell means in the first and second paths.

A device in accordance with the invention may have a significantly higher transmission characteristic than previously known devices. By sending the first and second components along what are effectively parallel optical paths, both of these components obtained from the original unpolarised incident radiation are utilized in the device. In the devices as illustrated in Figures 1 and 2, the initial polariser cuts down transmission through the system as a whole by 50% at least, with other components in the optical path adding to the reduction in transmission. The significantly improved transmission obtainable by making use of the invention means that devices based on the electro-optic effect become practicable in applications for which previously they would not have been considered. A device in accordance with the invention does not require a collimated, polarised or monochromatic illuminant source in order to work.

For a typical device, a prior art arrangement such as that shown in Figure 1 may have a transmission of approximately 42% whereas in a comparable device in accordance with the invention, transmissions of 80% may be achieved.

The term "optical" as used in this specification is intended to cover not only the visible parts of the spectrum but also the ultra-violet and far infra-red ranges also. For a particular device, the components included must be optimised for the parts of the

spectrum at which it is intended to operate.

A device in accordance with the invention may be used as a shutter in applications such as for example gated TV cameras (which may use CCD or other solid state sensors), laser gated TV cameras, multicolour cameras and displays, holographic displays, mid-infra-red range thermal cameras (operating at wavelengths of 3 to 5 microns for example), and thermal modulators for thermal cameras.

A device according to the present invention may be used as a voltage controlled attenuator. A varying voltage may be applied to the birefringent cell means to control transmission through the device. Thus where the output of the device is directed onto a sensor, the transmission may be controlled such that the sensor is operated at its optimum level of incident light. The transmission may be controlled using a separate circuit but in one advantageous embodiment, a control signal is derived from a sensor receiving the output from the device. For example, a CCD sensor output may be used to provide a feedback signal for the birefringent cell means. The device may be used to control light transmission where the output is to be received in turn by different sensors having different characteristics and/or where the input optical radiation to the device has changing characteristics, for example to view a scene under daylight conditions and also at night when illuminated by a laser source.

Where the device is used to deliver light from a scene to a sensor, such as a CCD sensor, there may be occasions where a bright point source in the scene causes an undesirable voltage spike at the output of the sensor during frame intervals. By

controlling transmission through the device, this may be avoided by ensuring that the device is non-transmissive during the frame intervals. This may be done for all frame intervals during normal operation as a precaution or only when conditions are such that a voltage spike is generated.

The invention is applicable to any device which uses the birefringence effect. For example, the birefringent cell means may comprise a Pockel cell or cells, Kerr cell or cells or LCD cells.

A particularly suitable material for use in a birefringent cell means is lanthanum-modified lead zirconate titanate (PLZT). Such materials may be tailored so as to control the magnitude of the birefringence for example by adjusting the percentage of lanthanum included in the material.

In a preferred embodiment, the cell means comprises a first cell in the first path and a second different cell in the second path. However, in an alternative embodiment, the cell means may comprise a single cell which is included in the both the first and second paths, the first and second components being applied to different regions of the single cell.

The polarising beam splitter may comprise a polarising separator such as a polarising beam splitter cube. In a preferred device, the polarising separator is such that it produces a transmitted component in one direction and a reflected component at 90^0 to the transmitted component, with the first and second components being linearly

polarised in different directions. Other cubes are available which produce transmitted and reflected components separated by other angles, for example 45^0. For example a Glan-Thompson polarizer gives 40^0.

In a preferred embodiment of the invention, the cell means includes a plurality of birefringent cells in the first path and a plurality of birefringent cells in the second path. By cascading the cells in each path, increased transmission, repetition rate and switching speeds are achievable.

In one embodiment the optical outputs of the first and second optical paths are kept separate. These outputs may be separately processed subsequently or may be combined following conversion from optical form into, say, electrical signals. For example, a first CCD sensor may receive the optical component from the first path and a second CCD sensor the component from the second path and the electrical outputs of the CCDs combined to give an output video signal. In another embodiment, the optical outputs of the first and second paths are optically combined. In a shutter, for example, this combined output may then be applied to a single optical sensor, such as a single CCD sensor or camera tube. The optical paths must be adjusted such that when the outputs are combined, they are in register with one another. It may be useful for some devices to include a moveable reflective surface, such as a prism , within the device for adjustment of the paths relative to one another to permit correct registration to be obtained.

In a preferred embodiment of the invention, the polarising beam splitter and

birefringent cell means form part of a single component. The component may also incorporate an optical combiner in those embodiments where the optical outputs are combined. This is particularly advantageous as it enables the geometry of the device and the properties of the components to be selected during assembly and subsequently the single component may be handled, for example, for shipping or when assembling it into a larger arrangement whilst maintaining the correct alignments, removing the need for subsequent adjustments. The optical combiner may be a cube or a prism, for example. Where the device is included within, say, a camera in which a focussing lens system is used to focus the image onto the camera, the device may be incorporated in the focussing system, for example, being located between elements of the focussing system itself.

A device in accordance with the invention may be used as a switch which modulates the applied input radiation between on and off states only, or in other arrangements, the cell means may be controlled to produce an intermediate state or states, or a continuous gradient between states. Thus, in one advantageous embodiment, the cell means may be controlled so as to switch between a transmissive state, an off state and a single intermediate state. This is particularly suitable for those applications in which it is important to be able to switch from a fully transmissive state to a state in which a significant proportion of incoming radiation is blocked in a very short time, for example in a system which uses a laser to illuminate a scene, where it is necessary to protect an optical sensor from scattered laser radiation occurring in its close vicinity immediately subsequent to the generation of a laser pulse.

In a preferred embodiment, the optic axis or axes of the birefringent cell means are rotated in one path relative to those in the other path, permitting a wider acceptance angle for the device and also reducing or eliminating aliasing effects which might otherwise occur in those systems where the outputs are re-combined.

A device in accordance with the invention may be used to extract from a viewed scene details of either vertically or horizontally polarised components which occur in that scene.

Some ways in which the invention may be performed are now described by way of example with reference to the accompanying drawings, in which:

Figure 3 schematically illustrates an optical arrangement incorporating a device in accordance with the invention and having two CCD sensors;
Figure 4 schematically illustrates a cascaded parallel shutter in accordance with the invention;

Figure 5 schematically shows another arrangement in accordance with the invention having a single output;

Figure 6 schematically illustrates another device in accordance with the invention;

Figures 7, 8 and 9 are explanatory diagrams relating to the device of Figure 6; and

Figures 10, 11, 12 13 and 14 schematically show other devices in accordance with the invention.

With reference to Figure 3, a shutter arrangement includes a polarising beam splitter cube 1 at which unpolarised input radiation is received in the direction shown by the arrow. The cube 1 acts to split randomly polarised input light into two components, one being transmitted straight through the cube 1 to give a beam 2 which is linearly polarised with P-polarisation, and the other component being reflected through 90° to give an output beam 3 which is also highly polarised having a linear S-polarisation. The reflected beam 3 is applied to a prism 4 where it is redirected onto a first birefringent cell C1, the output of which is directed to an analyser, in this case an output polariser P2. This first optical path also includes a CCD sensor 5 arranged to receive the output from polariser P2. There is a second optical path through the system parallel to the first path which includes a second birefringent cell C2, a second output polariser P4 and a second CCD sensor 6. Any light incident on the CCD sensors 5 and 6 produces a charge pattern representative of the amount of radiation incident thereon which can be electronically read out and combined at combiner 7 to give a video output signal at 8.

When no optical field is applied to either of the cells C1 and C2, there is no change in the direction of polarisation of light transmitted therethrough and subsequently incident on output polarisers P2 and P4. Thus, substantially no optical radiation is incident on the CCD sensors 5 and 6. When an electrical field is applied to both cells C1 and C2, the resultant rotation of the linearly polarised output light is transmitted

through polarisers P2 and P4 to reach the CCD sensors 5 and 6. The outputs of the CCD sensors 5 and 6 are controlled to add inregistration so as to give a combined video output signal at 8. By using two parallel optical paths through the shutter, the transmission is effectively doubled compare to the simple optical shutter shown in Figure 1. In the arrangement shown in Figure 3, the transmission T_{ON} = (Ux P1 x C1 x P2) + (U x P1 x C2 x P4) which is approximately P1 x C1 x P2 giving a transmission of approximately 80%, U being 0.5 (being the conversion of unpolarised light to polarised light), P1 and P2 are both approximately 0.9 and the transmission of C1 is approximately 0.9.

The material used in the birefringent cells C1 and C2 is PLZT which is commercially available. The first and second cells C1 and C2 could be replaced by a single cell which is extensive across both optical paths.

With reference to Figure 4, a shutter in accordance with the invention includes the components of the device shown in Figure 3 and having the same reference numerals for clarity. In addition, the first optical path also includes a second birefringent cell C2 which uses PLZT and a second polariser P3 interposed between the first polariser P2 and the CCD sensor 5. The second optical path, which is parallel to the first, includes an additional birefringent cell C4, again of PLZT, and a second polariser P5 located in front of the CCD sensor 6. Again, the outputs of the CCDs 5 and 6 are combined at 7 to give a video output at 8. As in the Figure 3 embodiment, the polarising beam splitter cube 1 produces a transmitted beam of one polarisation and a reflected beam of another polarisation. Thus, again, instead of the transmission being

reduced by 50% at the first polariser, both beam components contribute to the final output signal. By using two cells in each of the parallel optical paths, the transmission, power requirements and speed of switching are improved compared to the Figure 3 device. In a variation of this configuration, the cells C1 and C3 are replaced by a larger single cell, and cells C2 and C4 are replaced by a second larger single cell.

With reference to Figure 5, a shutter in accordance with the invention has an input polarising beam splitter 1. Linearly polarised light reflected at 1 is transmitted along a first path via prism 4 to a first birefringent cell C_1 and passes via a combiner 8 to a CCD sensor 9. Light transmitted by the beam splitter 1 and polarised orthogonal to that in the first path is transmitted to a second cell C_3 and is then directed onto the combiner 8 by a second prism 10 where it is reflected and combined with light from the first path to give a single output to the CCD 9.

With reference to Figure 6 this shows another shutter in accordance with the invention which includes two parallel optical paths each of which incorporates cascaded birefringent cells. Input radiation is applied to the polarising beam splitter 1. The reflected component is transmitted via a first cell C_1 and onto a reflecting polariser P2 from whence it is directed onto a second C_2 and to a combiner 8 which includes a polariser 11, which acts as the analyser. The light is then incident on a single CCD camera 9. The transmitted component from beam splitter 1 is similarly directed via a cell C_3 ,a reflecting polariser P4 and a second cell C_4, being finally incident on a second reflecting polariser 11 where it is combined with the originally reflected

component to give a single output.

The device offers improved transmission enabling a TV camera to be used, for example, for pulsed laser viewing under total darkness conditions. In addition, the cells C_1, C_2, C_3 and C_4 may be operated so as to give a three-state transmission path between the input and the CCD display output. This is particularly useful for active laser cameras. When the laser is pulsed, there may be scattering close to the sensor from, say, the surrounding atmosphere. It is thus essential to effectively shield the sensor from outgoing laser emission. After a finite delay, useful image information must be extracted from a scene being viewed but this requires the transmission to be extremely good. Thus switching is achieved between maximum extinction of 10^{-4} during which time the laser fires, an intermediate extinction level of 10^{-2} and a maximum transmission state of approximately 70% during which received imagery is extracted. By controlling when voltages are applied to the cells C_1 to C_4, these three states may be achieved.

Figure 7 is an explanatory diagram concerning the generation of the three transmission states. Figure 7a shows the PLZT transfer function, giving the transmission achieved for a particular applied voltage, the three voltage levels being 400 volts, 500 volts and 700 volts. Figure 7b illustrates the temporal function of the PLZT material, showing transmission against response time.

For a particular situation where it is wished to block transmission during emission of a laser pulse but permit the laser return from the illuminated scene to pass through the

device, the transmissive states are as illustrated in Figures 8a, 8b and 8c. The laser pulse is emitted at time t1 shown at Figure 8a and the return received at time t2. Figure 8b shows the state of the shutter, which during time period a the shutter is fully off, at time c the shutter is fully on, being at maximum transmission, and at other times, the shutter is partially off, shown at d. The pulses shown in Figure 8b are ideal and those achievable using the device of Figure 6 and a three state drive are illustrated in Figure 8c, where it can be seen the rise and fall of the transmission level during laser emission t1 is about 5 microseconds duration and the fully on state occurs for approximately 1 microsecond.

Figure 9 schematically shows two cells C1 and C2 in series connected so as to achieve the three state drive. This is repeated for the other two cells C3 and C4 in the other optical path through the device.

In the arrangement shown in Figure 6, the digital electrodes laid down on the surfaces of the cells C_1 to C_4 are arranged so such that they are angled with respect to each other to avoid aliasing. In the Figure 6 arrangement, the angles of the electrodes of C_1 are + 22%, for C_2 + 45%, for C_3 - 22% and C_4 - 45%.

In the device of Figure 6, a control signal from the ccD 9 may be applied to the cells C1, C2, C3 and C4 to adjust transmission to ensure that the CCD 9 operates at optimum illumination levels. This may act, for example, to adjust for slowly varying ambient light conditions in a viewed scene.

The cells C1, C2, C3 and C4 may also be controlled so as to block transmission to the CCD 9 during frame intervals.

For each of the devices shown in Figures 3 to 6, it is possible to distinguish between vertically and horizontally polarised components of a viewed scene. For example, in the Figure 6 device, the vertical and horizontal polarised components in a scene may be separately viewed by firstly switching off C_3 and C_4 and viewing the scene transmitted via C_1 and C_2 and then switching off C_1 and C_2 and viewing via C_3 and C_4.

The device of Figure 6 may be modified by incorporating, for example, a blue pass filter in the first path and a red pass filter in the second path. For example, P2 may be a blue pass filter and P4 a red pass filter. Thus when the combined output is viewed, the colour present in the display will indicate the polarised states.

Colour separation may be achieved using a standard dichroic prism in which, say, blue light is reflected and red/green light is transmitted, or a triple colour dichroic arrangement in which light is separated into blue, red and green components.

The device shown in Figure 4 may also be used for polar viewing without the inclusion of optical colour filters. Colour can then be introduced by electrical processing.

Another embodiment of the invention is illustrated in Figure 10. This has an input

polar splitter 1 followed by a birefringent cell C1 and C2 in the respective reflected and transmitted paths. The light transmitted via cell C1 is reflected at P2 and is incident on a first CCD sensor 12. The transmitted light passes via cell C2 to a second CCD sensor 13. This arrangement avoids lateral inversion but involves unequal first and second path lengths.

Another device is illustrated in Figure 11 and includes a polar splitter 1 which divides the incident radiation. Light reflected at P1 is transmitted via a birefringent cell C1 to a reflective surface P2 followed by another surface P3 to a polar combiner 14 where it is combined with light transmitted via polar splitter 1 and a second birefringent cell C2, the combined output being received by a single CCD sensor 15.

With reference to Figure 12, another device includes a polar splitter 1 following which in each path is located a birefringent cell C1 and C2 the output of which is directed towards prisms 16 and 17, the light then being recombined at polar combiner 18 and the output directed towards a CCD sensor 19. The prism 17 is adjustable in position so as to enable precise adjustment of the light paths to be achieved. Thus, registration may be adjusted by moving one prism only. This device requires a single CCD only and also presents equal path lengths on both the first and second paths through the device.

With reference to Figure 13, another device includes two polarising cubes and two polarisers. One cube acts as a polar splitter 1 and the second cube as a combiner 20. Two prisms 21 and 22 are located in the first and second optical paths and birefringent

cells C1, C2, C3 and C4 are located between the cubes and prisms. In addition, two polarisers P1 and P2 are incorporated in the first and second optical paths.

With reference to Figure 14a, a device 23 similar to that shown in Figure 13 is located as a shutter between an input lens 24 and a CCD 25. The insertion of device 23 results in a longer system compared to an arrangement in which the device 23 is absent as illustrated in Figure 14b. In this arrangement the entry cube 1 of the device 23 is longer than the exit cube 20 because of the acceptance angle which is aperture and focal length dependent.

CLAIMS

1. An electro-optic device comprising: a polarising beam splitter which produces first and second differently polarised components from applied unpolarised optical radiation; first and second optical paths along which the first and second components respectively are directed; and birefringent cell means in the first and second paths.

2. A device as claimed in Claim 1 wherein the cell means comprises a first cell in the first path and a second different cell in the second path.

3. A device as claimed in Claim 1 or 2 wherein the cell means comprises a single cell which is included in both the first and second paths, the first and second components being applied to different regions of the single cell.

4. A device as claimed in Claim 1, 2 or 3 wherein the cell means is independently controllable in the first and second paths.

5. A device as claimed in any preceding claim wherein the cell means includes a plurality of birefringent cells in the first path and plurality of birefringent cells in the second path.

6. A device as claimed in any preceding claim wherein the optical outputs of the first and second paths are kept separate.

7. A device as claimed in any of Claims 1 to 5 wherein the optical outputs of the first and second paths are combined.

8. A device as claimed in any preceding claim and including optical sensor means arranged to receive the components after they have travelled along the first and second paths.

9. A device as claimed in Claim 8 wherein the optical sensor means includes CCD means.

10. A device as claimed in Claim 8 or 9 when dependent on Claim 6, wherein the outputs of the first and second optical paths are applied to respective different optical sensors and the outputs of the sensors subsequently combined.

11. A device as claimed in any preceding claim and including analyser means to receive the output of the birefringent cell means.

12. A device as claimed in any preceding claim wherein the beam splitter comprises a polarising beam splitter cube.

13. A device as claimed in any preceding claim wherein the birefringent cell means includes PLZT.

14. A device as claimed in any preceding claim wherein electrodes incorporated in

the cell means in one optical path are offset with respect to electrodes in the cell means in the other optical path.

15. A device as claimed in any preceding claim wherein the cell means is operable such as to produce three or more degrees of transmission through the device.

16. A device as claimed in any preceding claim wherein the birefringent cell means is controlled to maintain the optical output of the device within a pre-determined range during transmission.

17. a device as claimed in claim 16 and including a sensor for monitoring the output and means for deriving a control signal dependent on the monitored output and applying it to the birefringent cell means.

18. A device as claimed in any preceding claim wherein the birefringent cell means is controlled to prevent transmission during frame intervals of a sensor which receives the optical output.

19. A device as claimed in any preceding claim wherein at least the beam splitter and birefringent cell means are parts of a single component.

20. A device as claimed in Claim 19 when dependant on Claim 7 wherein an optical combiner for combining first and second components after transmission through the cell means forms part of the single component.

21. A device as claimed in any preceding claim wherein first and second polarised components are output in respective different colours.

22. A device as claimed im any preceding claim wherein the optic axis of the birefringent cell means in one path is rotated relative to that in the other path.

23. Camera apparatus including a device as claimed in any preceding claim.

24. Camera apparatus as claimed in Claim 23 wherein the device is included within the focussing system of the camera.

25. An electro-optic device substantially as illustrated in and described with reference to any one of Figures 3 to 14 of the accompanying drawings.

26. A shutter arrangement substantially as illustrated in and described with reference to any one of Figures 3 to 14 of the accompanying drawings.

Fig.1.

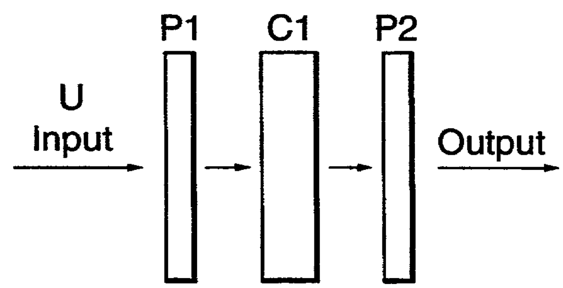


Fig.2.

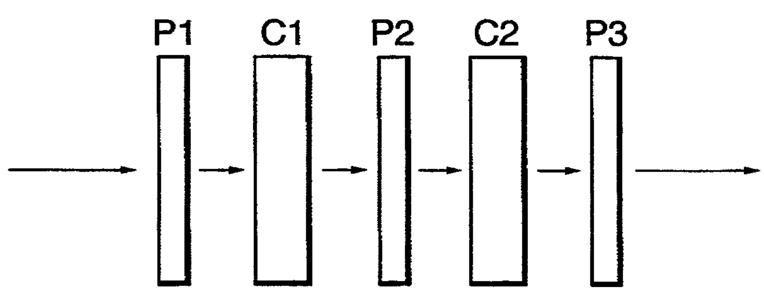


Fig.3.

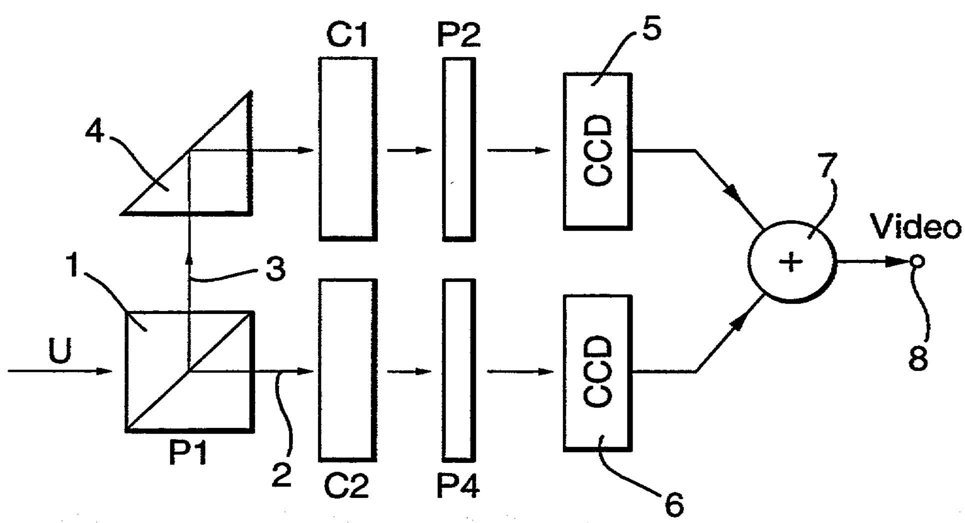


Fig.4.

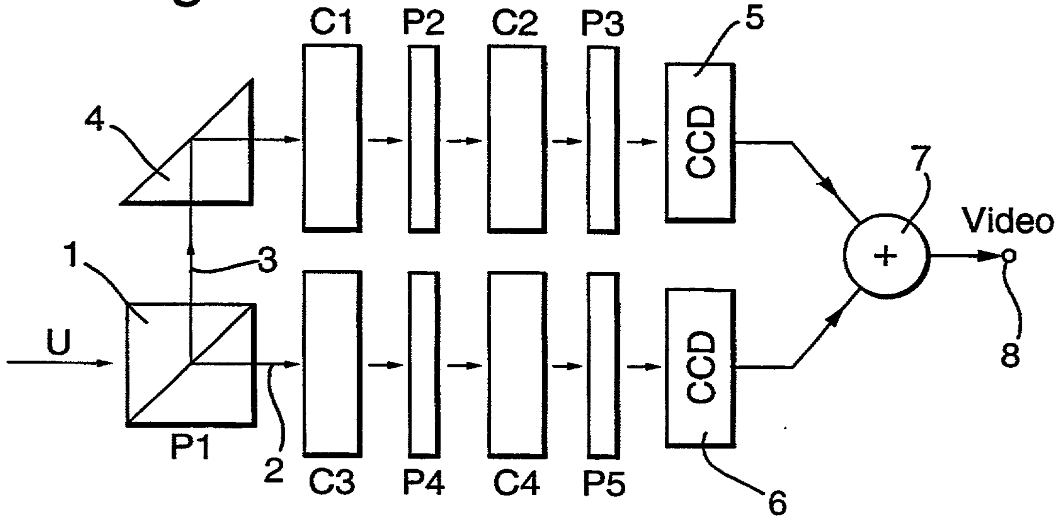


Fig.5.

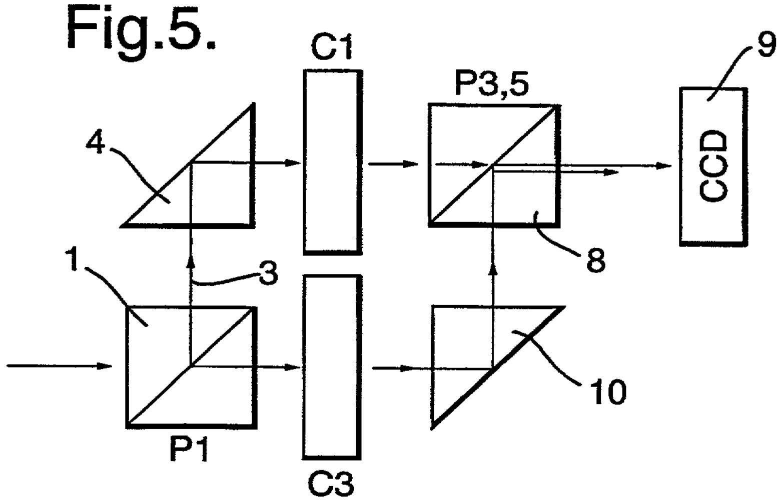


Fig.6.

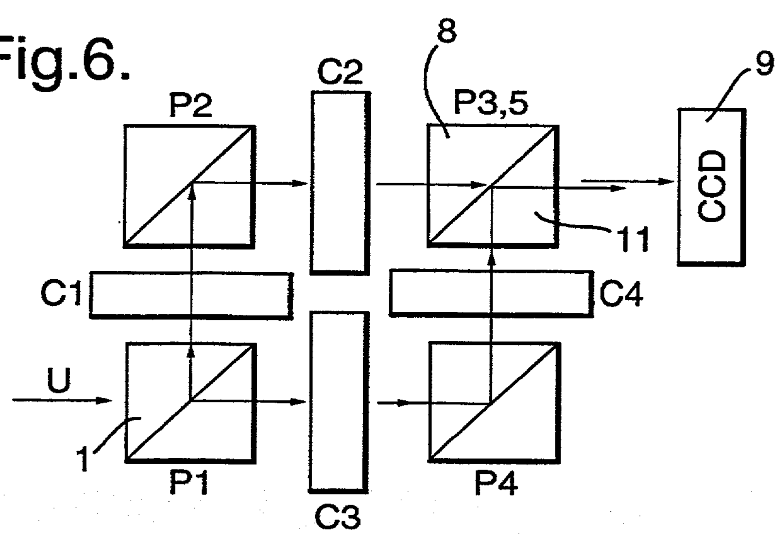


Fig.7a.

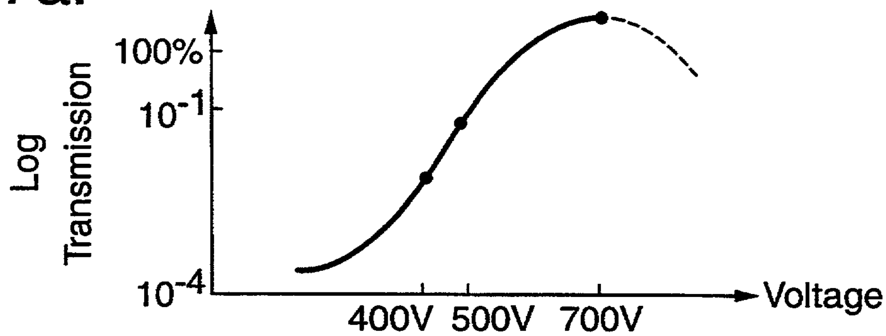


Fig.7b.

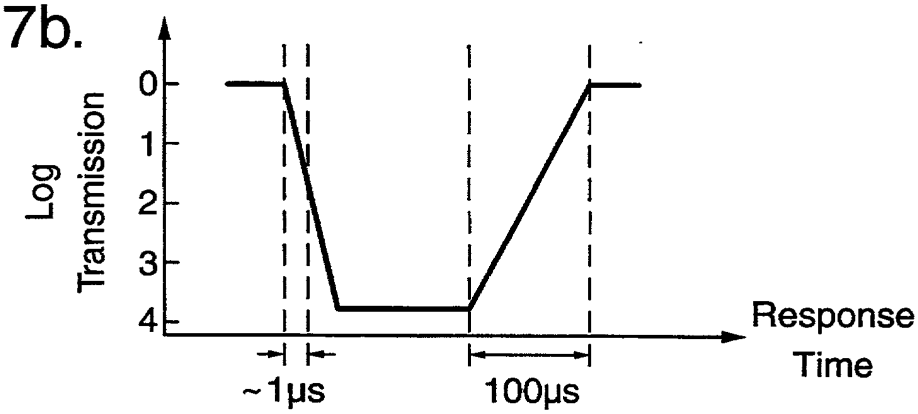


Fig.8a.

Fig.8b.

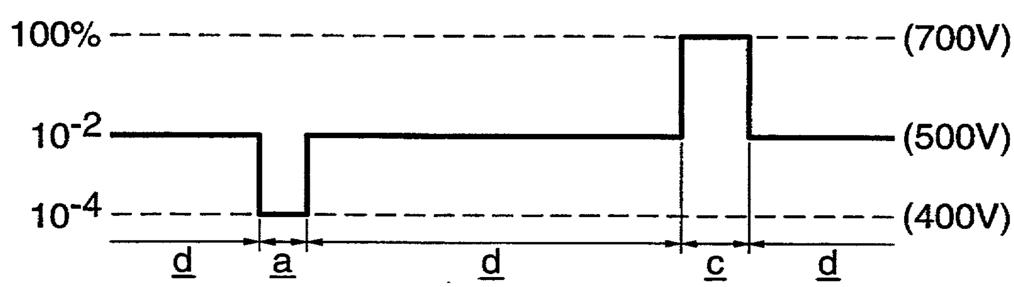


Fig.8c.

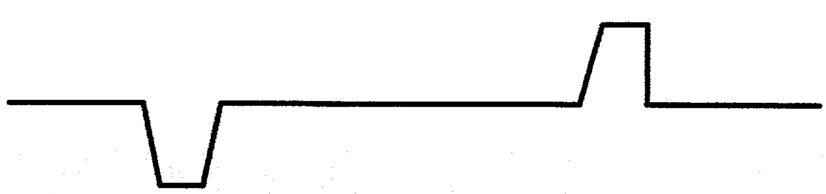


Fig.9.

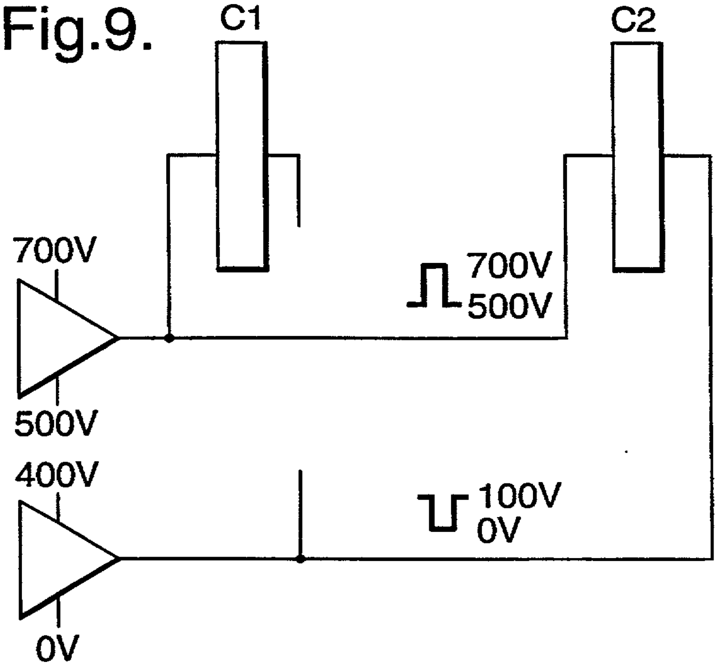


Fig.10.

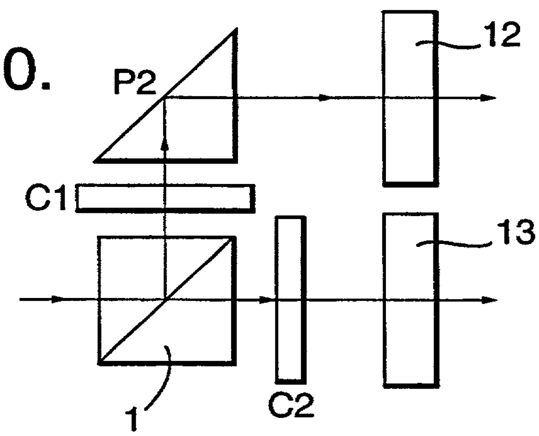


Fig.11.

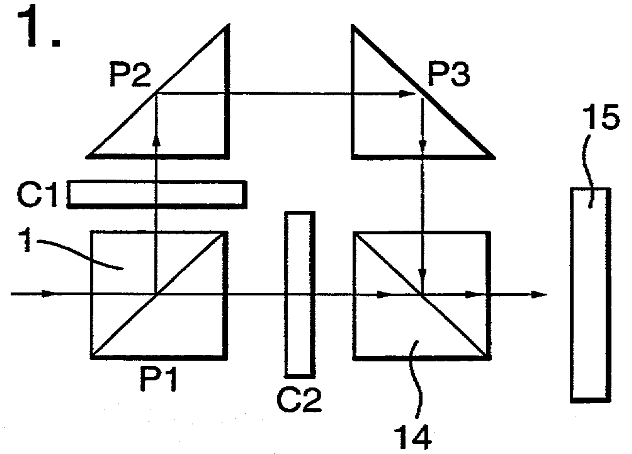


Fig.12.

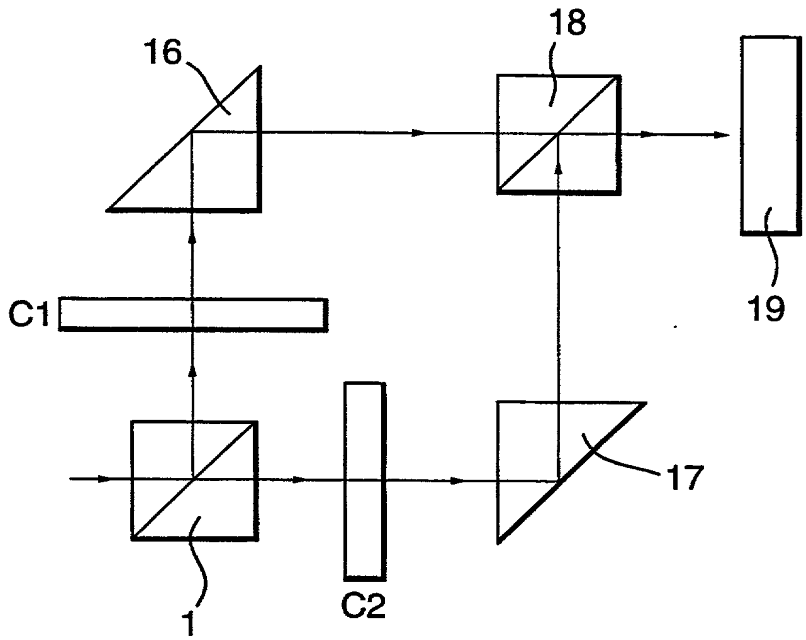


Fig.13.

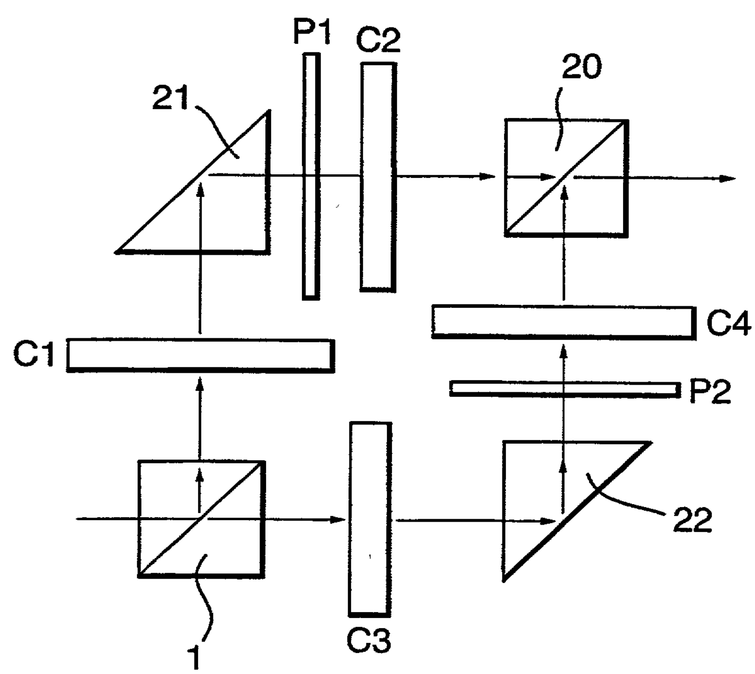


Fig.14a.

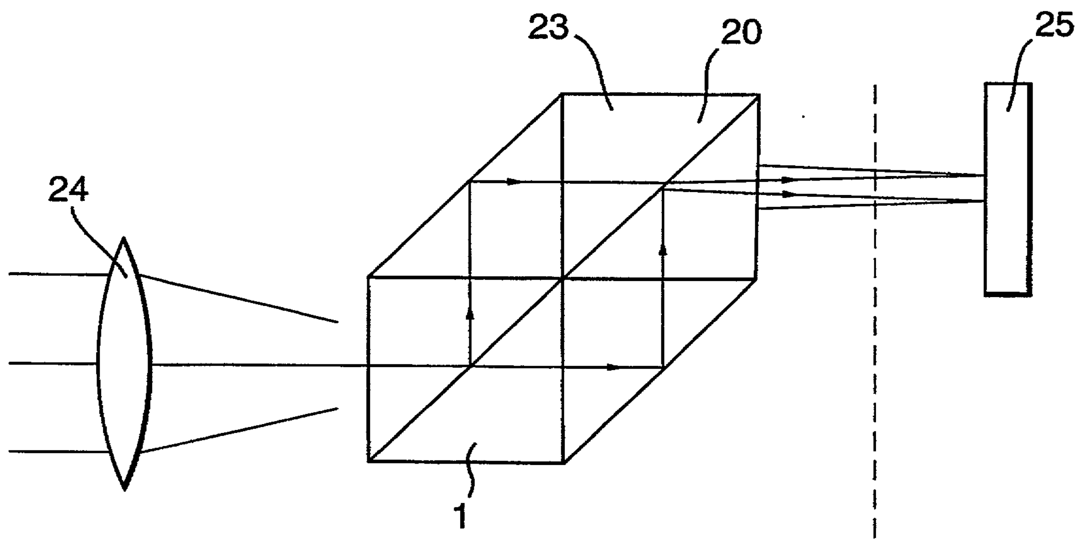
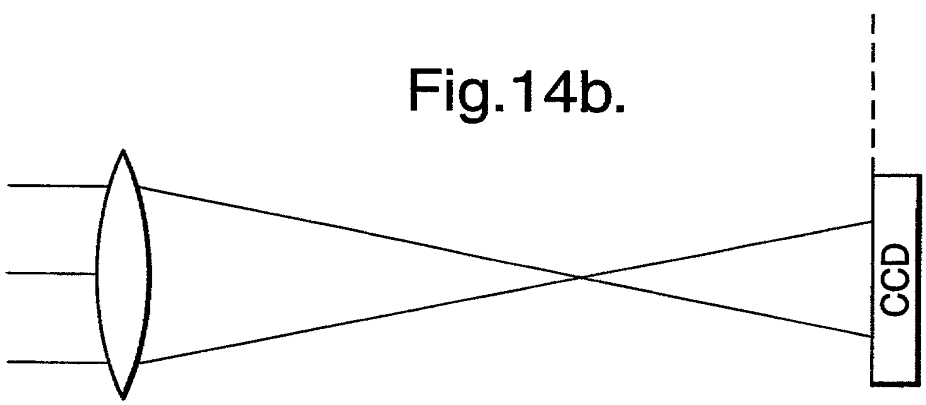


Fig.14b.



PTO/SB/01 (6-95)
Approved for use through 9/30/98 OMB 0651-0032
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U.S. Department of Commerce
Patent and Trademark Office

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION

☐ Declaration Submitted with Initial Filing OR ☒ Declaration Submitted after Initial Filing

Attorney Docket Number	P161800
First Named Inventor	Simon Howard SPENCER
COMPLETE IF KNOWN	
Application Number	09/926,592
Filing Date	November 23, 2001
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled :

ELECTRO-OPTIC DEVICES

(Title of the Invention)

the specification of which

☐ is attached hereto

OR

☒ was filed on (MM/DD/YYYY) November 23, 2001 as United States Application Number 09/926,592 ~~or~~ PCT International

Application Number PCT/GB00/01979 and was amended on (MM/DD/YYYY) May 24th 2000 (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119 (a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365 (a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	Certified Copy Attached? NO
9912072.7	GB	May 24th 1999	☐	☐	☒
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
PCT/GB00/01979	INTERNATIONAL	May 24, 2000	☐	☐	☒

☐ Additional foreign application numbers are listed on a supplemental priority sheet attached hereto:

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	
		☐ Additional provisional application numbers are listed on a supplemental priority sheet attached hereto.

Type a plus sign (+) inside this box → [+]

DECLARATION

ADDITIONAL INVENTOR(S) Supplemental Sheet

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

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Post Office Address	Danbury, Chelmsford, Essex, United Kingdom						
City	Chelmsford	State		Zip		Country	United Kingdom
Applicant Authority							

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name	WP William	Middle Initial	P	Family Name	PRITCHARD	Suffix e.g. Jr.	
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Residence: City	Chelmsford	State		Country	United Kingdom GBN	Citizenship	British
Post Office Address	WP ~~39 Woodhall Road, Chelmsford~~ 39 BAY TREE CLOSE						
Post Office Address	WP ~~Essex CM1 4AE, United Kingdom~~ NEWTON LONGVILLE BUCKS MK17 0DT						
City	Chelmsford	State		Zip	CM1 4AE	Country	United Kingdom
Applicant Authority							

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name		Middle Initial		Family Name		Suffix e.g. Jr.	
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		Zip		Country	
Applicant Authority							

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name		Middle Initial		Family Name		Suffix e.g. Jr.	
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		Zip		Country	
Applicant Authority							

☐ Additional inventors are being named on supplemental sheet(s) attached hereto